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(54) Grease composition.

- (57) A grease composition, having improved water resistance, adhesion and low temperature pumpability properties, which comprises
- (a) from 50 to 98 wt%, based on grease, of a lubricating oil;
 - (b) from 1 to 30 wt%, based on grease, of a thickener; and
 - (c) from 0.5 to 2.0 wt%, based on grease of polymer selected from either a defined block copolymer of the structure A-B, or a hydrogenated star-shaped polymer having a poly(divinylbenzene) nucleus and at least seven hydrogenated polyisoprene arms linked to said nucleus.
- The grease has an apparent viscosity of less than about 3500 poise (350 Pa.s) at 20 sec⁻¹.

This invention relates to a grease composition having improved adhesion and water resistance.

Many greases are subjected to operating conditions wherein the grease is exposed to an aqueous environment. Aqueous environments are detrimental to grease performance because of problems such as leaching of water soluble components and reduced adhesion. The use of polymers to impart desirable properties to greases is well-known. For example, a presentation by G. D. Hussey at the October, 1986 NLGI meeting in San Diego, California, discussed the alteration of grease characteristics using new generation polymers. However, many polymers must be incorporated at relatively high concentrations in order to impact the desired properties. This can lead to other problems such as poor pumpability, especially at low temperatures.

It would be desirable to have a polymer additive to greases which has good water resistance and adhesion properties at low concentrations while at the same time producing a grease with good pumpability.

This invention relates to a grease composition having improved water resistance, adhesion and low temperature pumpability properties which comprises:

- (a) from 50 to 90 wt%, based on grease of a lubricating oil;
- (b) from 1 to 30 wt%, based on grease of a thickener; and
- (c) from 0.5 to 2.0 wt%, based on grease of polymer selected from the group consisting of (1) a block copolymer of the structure A-B where A is a polymer block comprising at least about 75 percent by weight of condensed styrene units, no more than 25 percent of the aromatic unsaturation in said block being reduced by hydrogenation and B is hydrogenated polymer block comprising, prior to hydrogenation, at least 75 percent by weight of condensed isoprene units, at least 95 percent of the olefinic unsaturation in said block being reduced by hydrogenation, and (2) a hydrogenated star-shaped polymer having a poly(divinylbenzene) nucleus and at least seven hydrogenated polyisoprene arms linked to said nucleus; wherein the grease has an apparent viscosity of less than about 3500 poise (350 Pa.s) at 20 sec⁻¹.

Suitably the total of (a) + (b) + (c) will be over 60 wt.% of the grease composition, normally at least 80 wt.%, preferably either at least 85 wt.% or at least 90 wt.%.

A wide variety of lubricating oils can be employed in preparing the grease compositions of the present invention. Accordingly, the lubricating oil base can be any of the conventionally used mineral oils, synthetic hydrocarbon oils or synthetic ester oils, depending upon the particular grease being prepared. In general these lubricating oils will have a viscosity in the range of about 5 to about 10,000 cSt at 40°C, although typical applications will require an oil having a viscosity ranging from about 10 to about 1,000 cSt at 40°C. Mineral lubricating oil base stocks used in preparing the greases can be any conventionally refined base stocks derived from paraffinic, naphthenic and mixed base crudes. Synthetic lubricating oils that can be used include esters of glycols such as a C₁₃ oxo acid diester of tetraethylene glycol, or complex esters such as one formed from 1 mole of sebacic acid and 2 moles of tetraethylene glycol and 2 moles of 2-ethylhexanoic acid. Other synthetic oils that can be used include synthetic hydrocarbons such as polyalphaolefins; alkyl benzenes, e.g. alkylate bottoms from the alkylation of benzene with tetrapropylene, or the copolymers of ethylene and propylene; silicon oils, e.g. ethyl phenyl polysiloxanes, methyl polysiloxanes, etc.; polyglycol oils, e.g. those obtained by condensing butyl alcohol with propylene oxide; carbonate esters, e.g. the product of reacting C₈ oxo alcohol with ethyl carbonate to form a half ester followed by reaction of the latter with tetraethylene glycol, etc. Other suitable synthetic oils include the polyphenyl esters, e.g. those having from about 3 to 7 ether linkages and about 4 to 8 phenyl groups. The amount of lubricating oil in the grease can also vary broadly, but, typically, will range from about 50 to about 98 wt%, preferably from about 75 to about 95 wt%, of the grease.

The grease composition will also contain a thickener dispersed in the lubricating oil to form a base grease. However, the particular thickener employed is not critical and can vary broadly provided it is essentially water insoluble. For example, the thickener may be based on aluminum, barium, calcium, lithium soaps, or their complexes. Soap thickeners may be derived from a wide range of animal oils, vegetable oils, and greases as well as the fatty acids derived therefrom. These materials are well known in the art and are described in, for example, C. J. Boner, *Manufacture and Application of Lubricating Greases*, Chapter 4, Robert E. Krieger Publishing Company, Inc., New York (1971). Carbon black, silica, and clays may be used as well as dyes, polyureas, and other organic thickeners. Pyrrolidone based thickeners can also be used. Preferred thickeners are based on lithium soap, calcium soap, their complexes, or mixtures thereof. Particularly preferred is a lithium or lithium complex thickener that incorporates an hydroxy fatty acid having from 12 to 24 (preferably from 16 to 20) carbon atoms. A preferred hydroxy fatty acid is an hydroxy stearic acid (e.g., a 9-hydroxy or a 10-hydroxy stearic acid) of which 12-hydroxy stearic acid is most preferred (See U.S. Pat. No. 3,929,651, the disclosure of which is incorporated herein by reference). The amount of thickener in the lubricating composition will typically range from about: 1 to about 30 wt%. For most purposes, between about 5 to about 20 wt%, preferably between about 10 to about 15 wt%, of the thickener will be present in the composition. The grease preferably has a hardness between an NLGI rating of 0 to 2, preferably between 1 and 2 as measured by ASTM D217.

The grease composition also contains hydrogenated styrene-isoprene block copolymers or hydrogenated

polyisoprene star-shaped polymers. In the styrene/isoprene block copolymer of the structure A-B, the polymer A block is a polymerized styrene having an average molecular weight between about 10,000 and about 55,000, preferably about 25,000 and about 50,000. Polyisoprene is the conjugated diene employed in preparing the precursor block B. Preferably the polyisoprene block should have at least about 80%, preferably 88%, 1,4-structure which may be cis or trans and an average molecular weight between about 35,000 and 80,000. The weight ratio of block A to block B is between about 0.45:1 and 0.8:1, preferably 0.5:1 to 0.7:1. The average molecular weight of the styrene/isoprene block copolymers is between about 80,000 to about 120,000. Molecular weights referred to throughout this specification and appended claims are number average molecular weights.

The block copolymers are commercially available from Shell Chemical Company as Shellvis 40 and Shellvis 50. Such copolymers are prepared according to the methods described in U.S. Patent 3,772,196, which is incorporated herein by reference. The block copolymers are prepared using lithium-based initiators, preferably lithium alkyls such as lithium butyls or lithium amyls. Polymerization is usually conducted in solution in an inert solvent such as cyclohexane or alkanes such as butanes or pentanes and mixtures of the same. The first monomer to be polymerized (which may be either styrene or isoprene) is injected into the system and contacted with the polymerization initiator which is added in an amount calculated to provide the predetermined average molecular weight. Subsequent to obtaining the desired molecular weight and depletion of the monomer, the second monomer is then injected into the living polymer system and block polymerization occurs, resulting in the formulation of the living block copolymer poly(styrene)-polyisoprene which is then killed, e.g., by the addition of methanol.

This precursor is then subjected to selective hydrogenation to form the block copolymers. Preferably hydrogenation is conducted in the same solvent in which the polymer was prepared, utilizing a catalyst comprising the reaction product of aluminum alkyl and a nickel or cobalt carboxylate or alkoxide. A favored catalyst is the reaction product formed from triethyl aluminum and nickel octoate.

The temperatures and pressures employed in the hydrogenation step are adjusted such as to cause essentially complete hydrogenation of the polyisoprene block with essentially no effective hydrogenation of the monoalkenyl arene polymer block.

The polymer may be isolated from its solvent after its hydrogenation and dispersed in lubricating oil. This may be effected, for example, by adding a lubricating oil to the solution of hydrogenated polymer and thereafter evaporating the relatively volatile solvent.

The hydrogenated star polymer has a poly(divinylbenzene coupling agent) nucleus and hydrogenated polyisoprene arms linked to the nucleus. The average molecular weights of each arm are from about 15,000 to about 100,000, and the average molecular weight of the star polymer is between about 250,000 and 1,250,000, preferably 350,000 to 1,000,000.

The star polymers are commercially available from Shell Chemical Company as Shellvis® 200 and Shellvis® 250. These polymers are prepared using the methods described in U.S. Patent 4,116,917, which is incorporated herein by reference, and are generally produced by the process comprising the following reaction steps:

- (a) polymerizing isoprene in the presence of an ionic initiator to form a living polymer,
- (b) reacting the living polymer with a poly(divinylbenzene coupling agent) to form a star-shaped polymer, and
- (c) hydrogenating the star-shaped polymer to form a hydrogenated star-shaped polymer.

The living polymers produced from isoprene in reaction step (a) are the precursors of the hydrogenated polymer chains which extend outwardly from the poly(divinylbenzene coupling agent) nucleus.

As is well known, living polymers may be prepared by anionic solution polymerization of conjugated dienes and, optionally, mono-alkenyl arene compounds in the presence of an alkali metal or an alkali-metal hydrocarbon, e.g. sodium naphthalene, as anionic initiator. The preferred initiator is lithium or a monolithium hydrocarbon. Suitable lithium hydrocarbons include unsaturated compounds such as allyl lithium, methallyl lithium; aromatic compounds such as phenyllithium, the toyllithiums, the xylyllithiums and the naphthyllithiums and in particular the alkyl lithiums such as methylolithium, ethyllithium, propyllithium, butyllithium, amyllithium, hexyllithium, 2-ethylhexyllithium and n-hexadecyllithium. Secondary-butyllithium is the preferred initiator. The initiators may be added to the polymerization mixture in two or more stages optionally together with additional monomer. The living polymers are olefinically unsaturated. The concentration of the initiator used to prepare the living polymer may also vary between wide limits and is determined by the desired molecular weight of the living polymer.

The solvents in which the living polymers are formed are inert liquid solvents such as hydrocarbons e.g. aliphatic hydrocarbons, such as pentane, hexane, heptane, octane, 2-ethylhexane, nonane, decane, cyclohexane, methylcyclohexane or aromatic hydrocarbons e.g. benzene, toluene, ethylbenzene, the xylenes, diethyl-

benzenes, propylbenzenes. Cyclohexane is preferred. Mixtures of hydrocarbons e.g. lubricating oils may also be used.

The temperature at which the polymerization is carried out may vary between wide limits such as from -50°C to 150°C, preferably from about 200° to about 800°C. The reaction is suitably carried out in an inert atmosphere such as nitrogen and may be carried out under pressure e.g. a pressure of from about 0.5 to about 10 bars.

The living polymers produced in reaction step (a) are then reacted, in reaction step (b), with a polydivinylbenzene coupling agent. Polyalkenyl coupling agents, such as polydivinyl benzene, capable of forming star-shaped polymers are known. See generally, Fetters et al., U.S. Patent No. 3,985,830. They are usually compounds having at least two non-conjugated alkenyl groups. Such groups are usually attached to the same or different electron-withdrawing groups e.g. an aromatic nucleus. Such compounds have the property that at least two of the alkenyl groups are capable of independent reaction with different living polymers and in this respect are different from conventional conjugated diene polymerizable monomers such as butadiene, isoprene, etc.

The polyvinylbenzene coupling agent should be added to the living polymer after the polymerization of isoprene is substantially complete, i.e. the agent should only be added after substantially all of the isoprene monomer has been converted to living polymers.

The amount of polydivinylbenzene coupling agent added may vary between wide limits, but preferably at least 0.5 mole is used per mole of unsaturated living polymer. Amounts of from 1 to 15 moles, preferably from 1.5 to 5 moles are preferred. The amount, which may be added in two or more stages, is usually such so as to convert at least 80 or 85% of the living polymers into star-shaped polymers.

The reaction steps (b) may be carried out in the same solvent as for reaction step (a). A list of suitable solvents is given above. The reaction step (b) temperature may also vary between wide limits e.g. from 0° to 150°C., preferably from 20°C to 120°C. The reaction may also take place in an inert atmosphere e.g. nitrogen and under pressure e.g. a pressure of from 0.5 to 10 bars.

The star-shaped polymers prepared in reaction step (b) are characterized by having a dense center or nucleus of cross-linked poly(polydivinylbenzene coupling agent) and a number of arms of substantially linear polyisoprene extending outwardly therefrom. The number of arms may vary considerably, but is typically between 4 and 25, preferably from about 7 to about 15.

Such star-shaped polymers, which are still "living", may then be deactivated or "killed", in known manner, by the addition of a compound which reacts with the carbanionic end group. As examples of suitable deactivators may be mentioned, compounds with one or more active hydrogen atoms such as water, alcohols (e.g. methanol, ethanol, isopropanol, 2-ethylhexanol) or carboxylic acids (e.g. acetic acid), compounds with one active halogen atom, e.g. a chlorine atom (e.g. benzyl chloride, chloromethane), compounds with one ester group and carbon dioxide. If not deactivated in this way, the living star-shaped polymers will be killed by the hydrogenation step (c).

In step (c), the star-shaped polymers are hydrogenated by any suitable technique. Suitably at least 50%, preferably at least 70%, more preferably at least 90%, most preferably at least 95% of the original olefinic unsaturation is hydrogenated. Preferably less than 10%, more preferably less than 5% of such aromatic unsaturation is hydrogenated. The hydrogenation can be carried out in any desired way. A hydrogenation catalyst may be used e.g. a copper or molybdenum compound. Compounds containing noble metals or noble-metal compounds can be used as hydrogenation catalysts. Preference is given to catalyst containing a non-noble metal or a compound thereof of Group VIII of the Periodic Table, i.e. iron, cobalt and in particular, nickel. As examples may be mentioned, Raney nickel and nickel on kieselguhr. Special preference is given to hydrogenation catalysts which are obtained by causing metal hydrocarbyl compounds to react with organic compounds of any one of the group VIII metals iron, cobalt or nickel, the latter compounds containing at least one organic compound which is attached to the metal atom by means of an oxygen atom. Preference is given to hydrogenation catalysts obtained by causing an aluminum trialkyl (e.g. aluminum triethyl (Al(Et)₃) or aluminum triisobutyl) to react with a nickel salt of an organic acid (e.g. nickel diisopropyl salicylate, nickel naphthenate, nickel 2-ethyl hexanoate, nickel di-tert-butyl benzoate, nickel salts of saturated monocarboxylic acids obtained by reaction of olefins having from 4 to 20 carbon atoms in the molecule with carbon monoxide and water in the presence of acid catalysts) or with nickel enolates or phenolates (e.g. nickel acetylacetonate, the nickel salt of butylacetophenone).

The hydrogenation of the star-shaped polymer is very suitably conducted in solution in a solvent which is inert during the hydrogenation reaction. Saturated hydrocarbons and mixtures of saturated hydrocarbons are very suitable and it is of advantage to carry out the hydrogenation in the same solvent in which the polymerization has been effected.

The hydrogenation star-shaped polymer is then recovered in solid form from the solvent in which it is hy-

drogenated by a convenient technique such as by evaporation of the solvent.

While the addition of polymers to greases to alter the grease properties is known, the precise impact of a given polymer on a given grease cannot be predicted. The effectiveness or lack thereof of any polymer for modifying any particular grease property is dependent on the type of grease and thickener. Even for a given polymer, there may be trade-offs with regard to impact on different properties of the grease. Applicants have discovered that the water resistance adhesion and pumpability properties of a grease can be improved by adding a hydrogenated polyisoprene radial polymer or hydrogenated styrene-isoprene block copolymer at low concentrations of from 0.5 to 2.0 wt%, based on grease. While higher amounts of polymer may marginally improve water resistance, such higher amounts negatively impact pumpability, especially at the low temperatures common in many grease applications. For this reason, it is important that at the minimum dispensing temperature of the polymer-free grease, i.e., that temperature at which the grease reaches an ASTM D1092 viscosity of about 2000 to 3000 poise at 20 sec⁻¹, the viscosity of the same grease containing polymer be less than 3500 poise at 20 sec⁻¹, preferably be from 2000 to 3000 poise at 20 sec⁻¹ as measured by ASTM D1092. This allows improvement of the grease without imparting a reduction in dispensing properties which is noticeable to the user.

The grease composition may also contain small amounts of supplemental additives which include, but are not limited to, anti-corrosive agents, extreme pressure antiwear agents, pour point depressants, tackiness agents, oxidation inhibitors, dyes, and the like, which are incorporated for specific purposes. The total amount of these additives will typically range from about 2 to about 5 wt% based on total weight of the grease composition. In addition, solid lubricants such as molybdenum disulfide and graphite may be present in the composition -- typically from about 1 to about 5 wt%, preferably from about 1.5 to about 3 wt% for molybdenum disulfide and from about 3 to about 15 wt%, preferably from about 6 to about 12 wt% for graphite.

The grease composition of this invention is usually prepared in situ by chemically reacting or mechanically dispersing thickener components in the lubricating oil for from about 1 to about 8 hours or more (preferably from about 3 to about 6 hours) followed by heating at elevated temperature (e.g., from about 140°C to about 225°C, depending upon the particular thickener used) until the mixture thickens. In some cases (e.g. a simple lithium grease), a preformed thickener can be used. The mixture is then cooled to ambient temperature (typically about 60°C) during which time the ethylene copolymer and other additives are added. The polymer and the other additives can be added together or separately in any order.

The components of the grease composition can be mixed, blended, or milled in any number of ways which can readily be selected by one skilled in the art. Suitable means include external mixers, roll mills, internal mixtures, Banbury mixers, screw extruders, augers, colloid mills, homogenizers, and the like.

The grease composition of this invention may be suitably employed in essentially any application requiring good water resistance. Examples of such applications include wheel bearing, automotive chassis, fifth wheels, paper machine, wet-end bearings, open pit and underground mining equipment, construction equipment and the like.

This invention will be further understood by reference to the following examples which include a preferred embodiment of the invention.

EXAMPLE 1

This example is a screening test for water shedding and adhesion properties of various polymers in a lithium grease.

A series of lithium 12-hydroxystearate greases was prepared with (i) a conventional mineral oil basestock (180 cSt at 40°C), (ii) a 5 wt% treat of a multipurpose grease additive containing EP/antiwear and anticorrosion additives and (iii) polymer additives selected from Table 1. These were evaluated using a modified Roll Stability test (apparatus described in ASTM D1831) in which 100 grams of grease and 100 grams of water are mixed in the roll apparatus for 1 hour; at the end of the test the amount of water absorbed by grease, the change in penetration (measured by ASTM D1401), and the adhesion of the grease to the roller were evaluated. The low temperature Apparent Viscosity of each grease was also measured using the ASTM D1092 test, for which results are given at a temperature of -20°C and a shear rate of 20 reciprocal seconds. These results are shown in Table 2.

Table 1

Polymer	Description
A	2500 Melt Index Ethylenevinylacetate copolymer
B	200 Melt Index Maleic Acid modified Ethylenevinylacetate copolymer
C	50 Melt Index Polyethylene
D	Polyisobutylene (Molecular Weight 1500)
E	Hydrogenated Styrene-Butadiene Copolymer
F	Dispersant Ethylene-Propylene Block Copolymer
G	Hydrogenated Polyisoprene Radial Polymer
H	Hydrogenated Styrene-Isoprene Block Copolymer

TABLE 2

Polymer	Polymer Wt%	Soap Wt%	Penetration mm/10	Modified Roll Stability Test			Apparent Viscosity Poise @ -20°C and 20 s-l
				Water Absorbed ml	Adhesion	Change In Penetration mm/10	
None	0.0	11.9	275	80	Fair	26	6,500
A	3.8	9.9	292	47	Poor	24	9,500
B	3.8	9.9	309	66	None	27	12,500
C	4.1	11.5	285	100	None	27	14,000
D	12.8	10.9	290	46	Fair	7	5,800
G	3.6	9.5	285	47	Excellent	11	3,200

The results in Table 2 show that Polymers A, D, and G provided that best water shedding ability (water absorbed) in the Roll Stability test. Of these, D and G had the least effect on penetration, with G showing far

better adhesion to the roller after the termination of the test.

EXAMPLE 2

5 This example is a further screening test of various polymers set forth in Table 1 in a lithium complex grease.

A series of lithium complex greases were prepared from lithium 12-hydroxystearic acid and azelaic acid according to the methods of U.S. 3,791,973. These greases were prepared using (i) a conventional mineral oil basestock (100 cSt at 40°C), (ii) a 5 wt% treat of a multipurpose grease additive containing EP/antiwear and anticorrosion additives and (iii) polymer additives selected from Table 1. In addition to the Roll Stability and
10 Apparent Viscosity tests used in Example 1, the greases were evaluated in the ASTM D4049 Water Spray-Off test. The results are given in Table 3.

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TABLE 3

Polymer	Polymer Wt%	Soap Wt%	Penetration mm/10	Modified Roll Stability Test			Water Spray- Off, Wt%	Apparent Viscosity Poise @ -20°C and 20 s-1
				Water Absorbed ml	Adhesion	Change In Penetration mm/10		
None	0.0	12.6	295	75	Poor	4	> 95	3,300
D	9.0	11.6	292	68	Excellent	-14	92.3	4,300
E	3.0	11.5	288	45	Excellent	-14	--	7,100
F	3.0	11.5	308	44	Good	0	65.4	5,000
G	3.0	11.5	295	38	Excellent	-8	65.8	5,000
H	3.0	11.5	294	43	Excellent	-23	17	4,500

The results show that Polymers E, F, G and H were superior in water shedding ability. Of these, polymers E, G, and H showed superior adhesion after the modified Roll Stability test. Polymer H gave the overall best results when Water Spray-Off and Apparent Viscosity are further taken into consideration.

EXAMPLE 3

In this example a lithium complex grease of the type described in Example 2, but incorporating a 220 cSt conventional mineral oil basestock, was prepared. The effect of different concentrations of Polymer H on performance in the Water Spray-Off test, and the Apparent Viscosity test, were evaluated as shown in Table 4.

TABLE 4

Polymer	Polymer Wt%	Soap Wt%	Penetration mm/10	Water Spray-Off, Wt%	Apparent Viscosity
					Poise @ -10°C and 20 s-l
None	0.0	12.7	273	73.4	2,400
H	1.0	12.5	306	31.3	-
H	1.5	12.5	305	24.8	3,000
H	2.0	12.7	299	21.0	3,500
H	2.5	12.3	310	9.0	4,500
H	3.0	12.3	295	4.2	4,000

This Table illustrates that the degree of Water Spray-Off resistance is dependant upon concentration of Polymer H, but that the effect of incremental addition is diminished as concentration of polymer approaches 2.0 wt% based on grease. This occurs in concert with an increase in Apparent Viscosity which adversely impacts the pumpability of the grease.

EXAMPLE 4

In this example, a lithium complex grease of the type described in Example 2, and incorporating different concentrations of Polymer G, was evaluated in the modified Roll Stability test, and the results are given in Table 5.

TABLE 5

Polymer	Polymer Wt%	Soap Wt%	Penetration mm/10	Modified Roll Stability Test			Apparent Viscosity Poise @ -20°C and 20 s-1
				Water Absorbed ml	Adhesion	Change In Penetration mm/10	
None	0.0	12.6	295	75	Poor	4	3300
G	1.0	11.8	292	82	Excellent	6	--
G	1.5	11.7	300	64	Excellent	-	--
G	1.9	11.8	287	40	Excellent	0	3000
G	3.0	11.5	295	38	Excellent	-8	5000

This Table illustrates that the ability of grease treated with Polymer G to shed water increases as concentrations are increased to 1.9 wt%, but that little incremental benefit results from further addition of polymer.

Claims

1. A grease composition having improved water resistance, adhesion and low temperature pumpability properties which comprises:

5 (a) from 50 to 98 wt%, based on grease, of a lubricating oil;
 (b) from 1 to 30 wt%, based on grease, of a thickener; and
 (c) from 0.5 to 2.0 wt%, based on grease of polymer selected from the group consisting of (1) a block copolymer of the structure A-B where A is a polymer block comprising at least about 75 percent by weight of condensed styrene units, no more than 25 percent of the aromatic unsaturation in said block being reduced by hydrogenation and B is hydrogenated polymer block comprising, prior to hydrogenation, at least 75 percent by weight of condensed isoprene units, at least 95 percent of the olefinic unsaturation in said block being reduced by hydrogenation, and (2) a hydrogenated star-shaped polymer having a poly(divinylbenzene) nucleus and at least seven hydrogenated polyisoprene arms linked to said nucleus;

15 wherein the grease has an apparent viscosity of less than about 3500 poise (350 Pa.s) at 20 sec⁻¹.

2. The grease composition of claim 1 wherein the apparent viscosity is from about 2000 to 3000 poise (200 to 300 Pa.s) at 20 sec⁻¹.

20 3. The grease composition of claim 1 wherein the thickener is a lithium or lithium complex thickener which incorporates a C₁₂ to C₂₄ hydroxy fatty acid.

4. The grease composition of claim 1 wherein the block copolymer has an average molecular weight between about 10,000 and 55,000.

25 5. The grease composition of claim 1 wherein the star polymer has an average molecular weight from about 250,000 to 1,250,000.

6. The grease composition of claim 1 additionally containing from about 1 to 5 wt%, based on grease, of a molybdenum disulfide or graphite.

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